National Aeronautics and Space Administration

Unmanned Aircraft Systems Traffic Management (UTM)

SAFELY ENABLING UAS OPERATIONS IN LOW-ALTITUDE AIRSPACE

Parimal Kopardekar, Ph.D.

NASA Senior Technologist, Air Transportation System, and
UAS Traffic Management Principal Investigator

Outline

- Overview
- Architecture
- Approach and schedule
- FAA-NASA Research Transition Team deliverables
- Progress and next steps
- Summary

Overview

Low Altitude UAS Operations

- Small UAS forecast – 7M total, 2.6M commercial by 2020
- Vehicles are automated and airspace integration is necessary
- New entrants desire access and flexibility for operations
- Current users want to ensure safety and continued access
- Regulators need a way to put structures as needed
- Operational concept being developed to address beyond visual line of sight UAS operations under 400 ft AGL in uncontrolled airspace using UTM construct

What is UTM?

- UTM is an “air traffic management” ecosystem for uncontrolled airspace
- UTM utilizes industry’s ability to supply services under FAA’s regulatory authority where these services do not exist
- UTM development will ultimately identify services, roles/responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements for enabling the management of low-altitude uncontrolled UAS operations

UTM addresses critical gaps associated with lack of support for uncontrolled operations

How to enable multiple BVLOS operations in low-altitude airspace?

Key Operational Assumptions

- FAA maintains regulatory *AND* operational authority for airspace and traffic operations
- UTM is used by FAA to issue directives, constraints, and airspace configurations
- Air traffic controllers **are not required** to actively "control" every UAS in uncontrolled airspace or uncontrolled operations inside controlled airspace
- FAA has on-demand access to airspace users and can maintain situation awareness through UTM
- UTM roles/responsibilities: Regulator, UAS Operator, and UAS Service Supplier (USS)
- FAA Air Traffic can institute operational constraints for safety reasons anytime

Key principle is safely integrate UAS in uncontrolled airspace without burdening current ATM

UTM Principles and Services

Principles

- ❑ Users operate in airspace volumes as specified in authorizations, which are issued based on type of operation and operator/vehicle performance
- ❑ UAS stay clear of each other
- ❑ UAS and manned aircraft stay clear of each other
- ❑ UAS operator has complete awareness of airspace and other constraints
- ❑ Public safety UAS have priority over other UAS

Key UAS-related services

- ❑ Authorization/Authentication
- ❑ Airspace configuration and static and dynamic geo-fence definitions
- ❑ Track and locate
- ❑ Communications and control (spectrum)
- ❑ Weather and wind prediction and sensing
- ❑ Conflict avoidance (e.g., airspace notification)
- ❑ Demand/capacity management
- ❑ Large-scale contingency management (e.g., GPS or cell outage)

Defining Operator and Regulator/ANSP Roles

UAS Operator

- Assure communication, navigation, and surveillance (CNS) for vehicle
- Register
- Train/qualify to operate
- Avoid other aircraft, terrain, and obstacles
- Comply with airspace constraints
- Avoid incompatible weather

Regulator/Air Navigation Service Provider

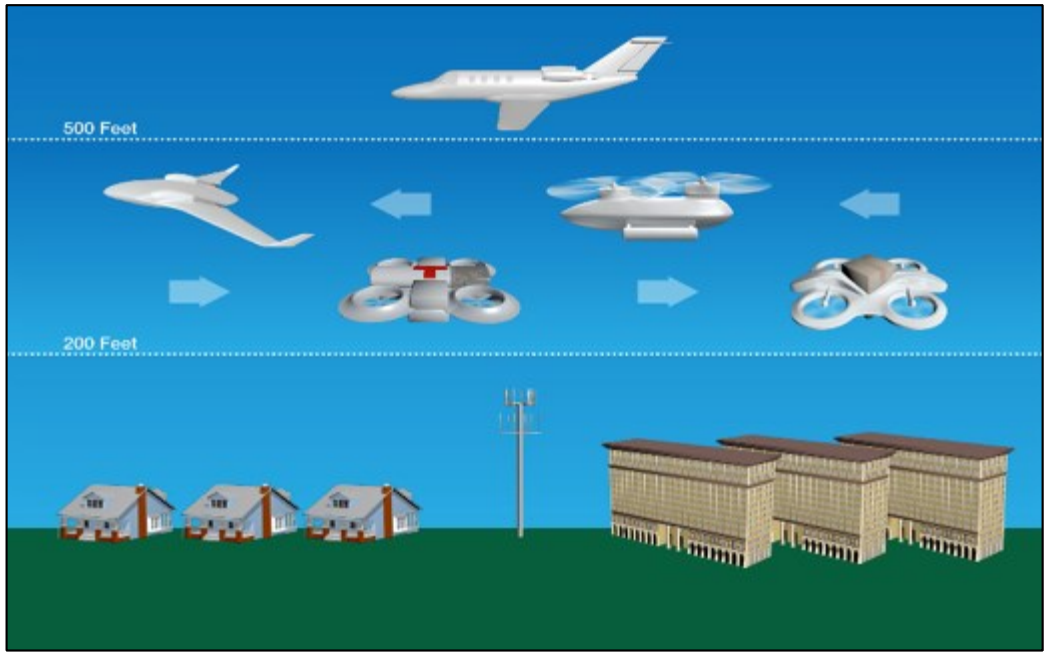
- Define and inform airspace constraints
- Facilitate collaboration among UAS operators for de-confliction
- If future demand warrants, provide air traffic management
  - Through near real-time airspace control
  - Through air traffic control integrated with manned aircraft traffic control, where needed

Third-party entities may provide support services but are not separately categorized or regulated

Supporting Functions

Wind & Weather Integration

- Operator responsibility, may be provided by third party
- Actual and predicted winds/weather
- No unique approval required



UTM Research and Development

Operations Considerations

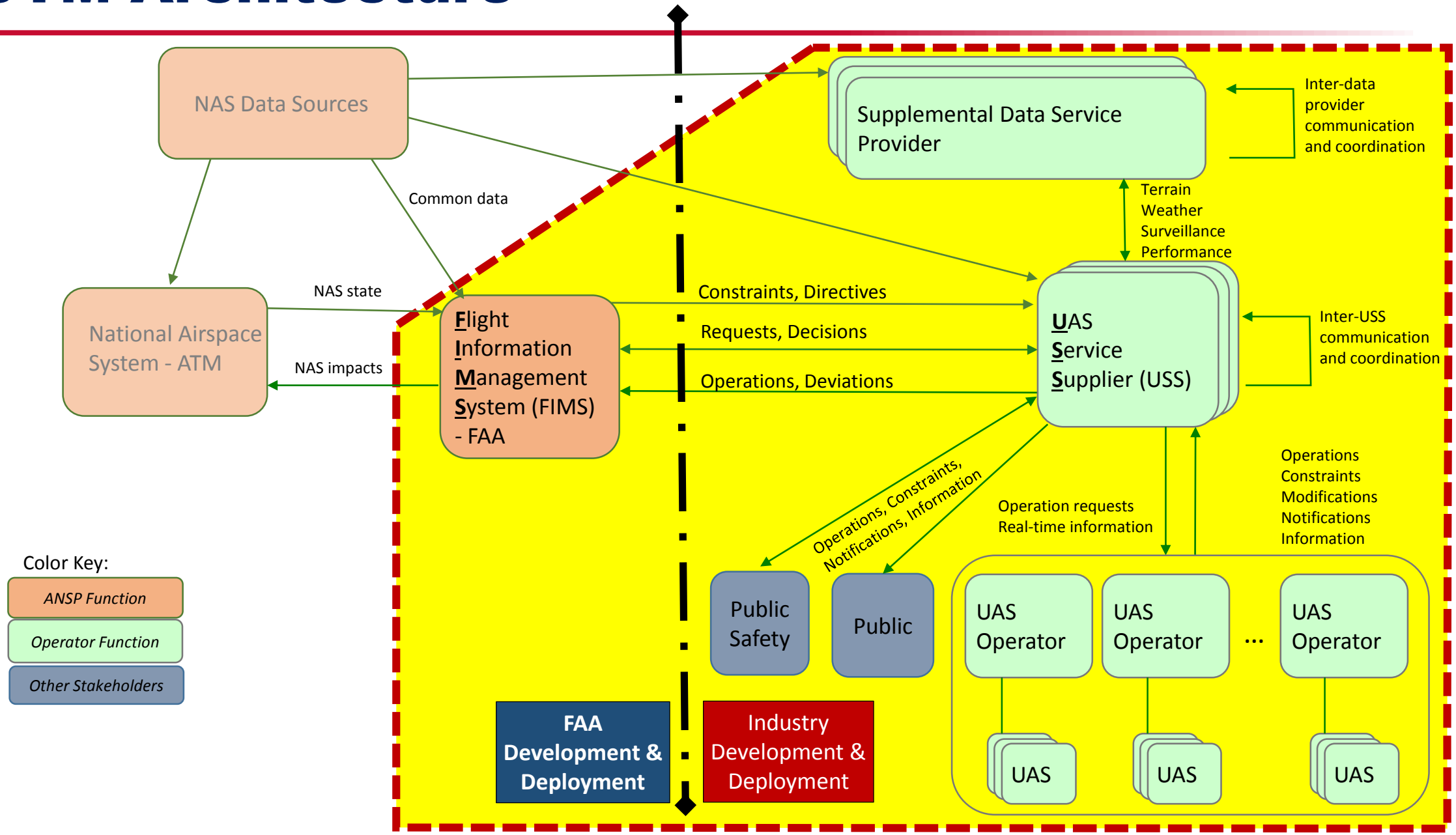
- Overarching architecture
- Scheduling and planning
- Dynamic constraints
- Real-time tracking integration
- Weather and wind
- Alerts:
  - Demand/capacity alerts
  - Safety critical events
  - Priority access enabling (public safety)
  - All clear or all land alerts
- Data exchange protocols
- Cyber security
- Connection to FAA systems

Vehicle Considerations

- Low SWAP DAA
- Vehicle tracking: cell, satellite, ADS-B, pseudo-lites
- Reliable control system
- Geo-fencing conformance
- Safe landing
- Cyber secure communications
- Ultra-noise vehicles
- Long endurance
- GPS free/degraded conditions
- Autonomous last/first 50 feet operations

Architecture

UTM Architecture



UTM Approach and Schedule

UTM Technical Capability Levels (TCLs)

Capability 1: Demonstrated how to enable multiple operations under constraints

- Notification of area of operation
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot

Product: Overall con ops, architecture, and roles

Capability 2: Demonstrated How to Enable Expanded Multiple Operations

- Beyond visual line-of-sight
- Tracking and low density operations
- Sparsely populated areas
- Procedures and “rules-of-the road”
- Longer range applications

Product: Requirements for multiple BVLOS operations including off-nominal dynamic changes

Capability 3: Focuses on how to Enable Multiple Heterogeneous Operations

- Beyond visual line of sight/expanded
- Over moderately populated land
- Some interaction with manned aircraft
- Tracking, V2V, V2UTM and internet connected

Product: Requirements for heterogeneous operations

Capability 4: Focuses on Enabling Multiple Heterogeneous High Density Urban Operations

- Beyond visual line of sight
- Urban environments, higher density
- Autonomous V2V, internet connected
- Large-scale contingencies mitigation
- Urban use cases

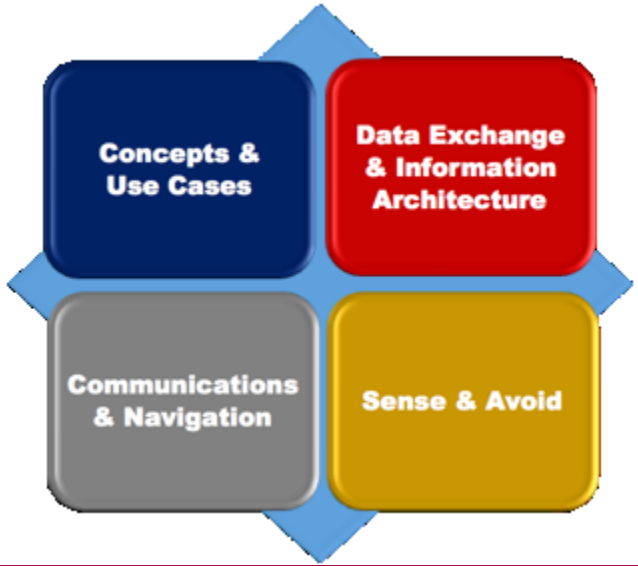
Product: Requirements to manage contingencies in high density, heterogeneous, and constrained operations

Risk-based approach: depends on application and geography

FAA-NASA Research Transition Team (RTT) Deliverables

RTT Plan & Key Deliverables

- **Near-term priorities**
  - Joint UTM Project Plan (JUMP) – December 2016 (Completed)
  - RTT Research plan – January 2017
  - UTM Pilot project – April 2017-2019
- **Execution**
  - March 2016 – December 2020



Key RTT Deliverables (FAA needs)

- Tech transfer - to FAA and industry
  - Concepts and requirements for data exchange and architecture, communication/navigation and detect/sense and avoid
    - Cloud-based architecture and Conops
    - Multiple, coordinated UAS BVLOS operations
    - Multiple BVLOS UAS and manned operations
    - Multiple operations in urban airspace
- Tech transfer to FAA
  - Flight Information Management System prototype (software prototype, application protocol interface description, algorithms, functional requirements)

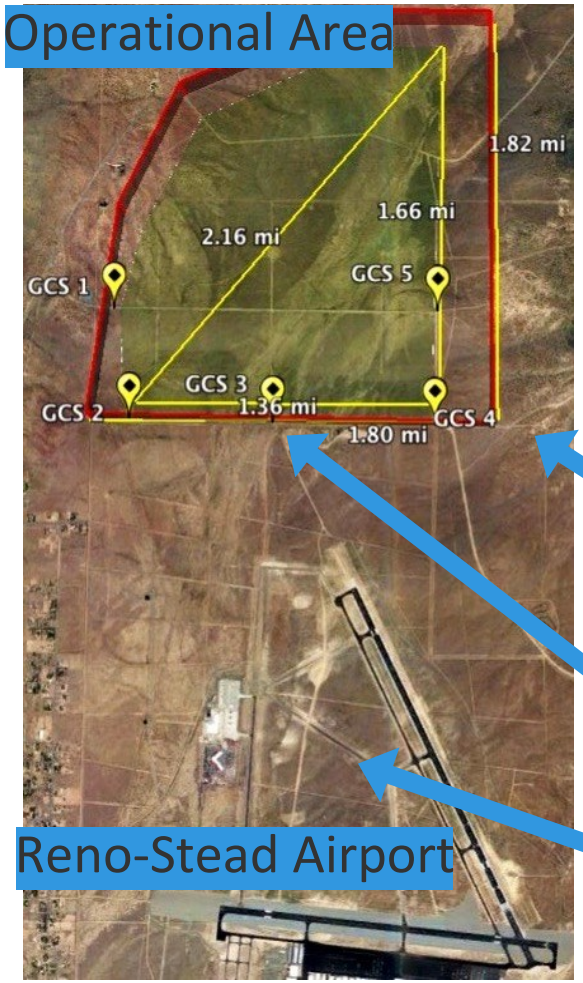
FAA-NASA Key RTT Deliverable

- Joint FAA-NASA UTM Pilot Program

RTT will culminate into key technical transfers to FAA and joint pilot program plan and execution

Progress and Next Steps

UTM TCL 2 Demonstration (October 2016 at Reno-Stead)



SRHawk Radar

Used to detect small UAS

Weather Equipment

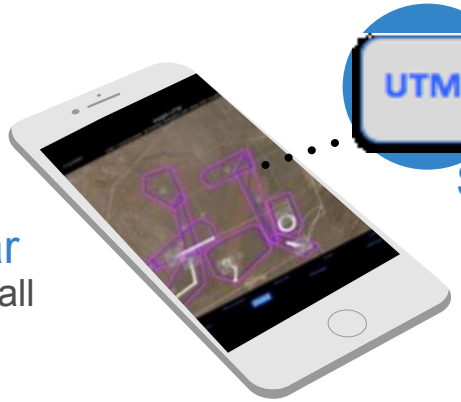
30 ft weather tower, sodar and lidar are used to measure atmospheric boundary layer

LSTAR Radar

Used to detect manned aircraft

Live-Virtual Constructive Environment

Altitude Stratified Operations



Situation Awareness Displays

Critical alerts, operational plan information and map displays

2 + 3 = 5

Expanded

Flights up to 1.5 miles away from the pilot in command

Visual Line of Sight

Hypothetical missions based on industry use cases

Simultaneous Operations

TCL 1 and 2 Demo and Preliminary Results

UTM TCL 1 and TCL 2 Demonstration Objectives

TCL 1

Evaluate the feasibility of multiple VLOS operations using scheduling and planning through an API connection to the UTM research platform

TCL 2

Evaluate the feasibility of multiple BVLOS operations using a UTM research platform

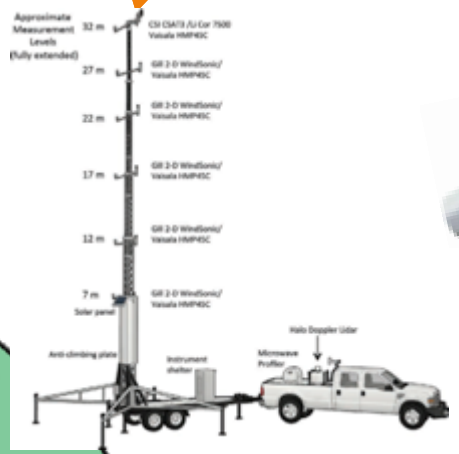
TCL 1: Multiple VLOS Operations

UAS Range

Elevation: 166 feet MSL

Flat Agricultural Farmland

Operations at 2 Locations



Weather Sensors

100 ft Weather Tower

Radiosonde Weather Balloon

Remote Automated Weather Station

Acoustic Sensors

SRHawk Radar

Used to detect small UAS

UTM TCL 1 Demonstration Highlights

Days of Flight
8

11 Partner Organizations

2 Simultaneous VLOS Operations

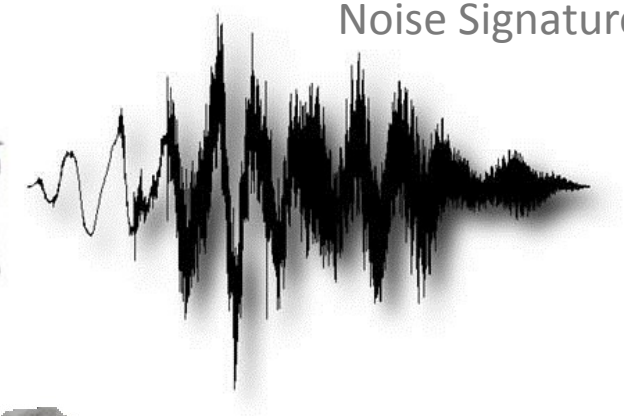
10 UAS Platforms

4
Test Conditions

108
Flights

18
Flight Hours

TCL 1 Demonstration Objectives

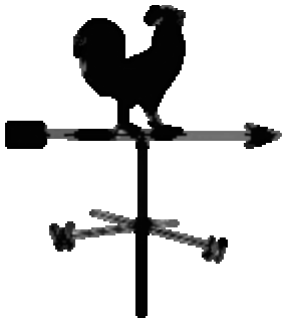


Objective 5: Collect Data on Noise Signature of UAS Vehicles

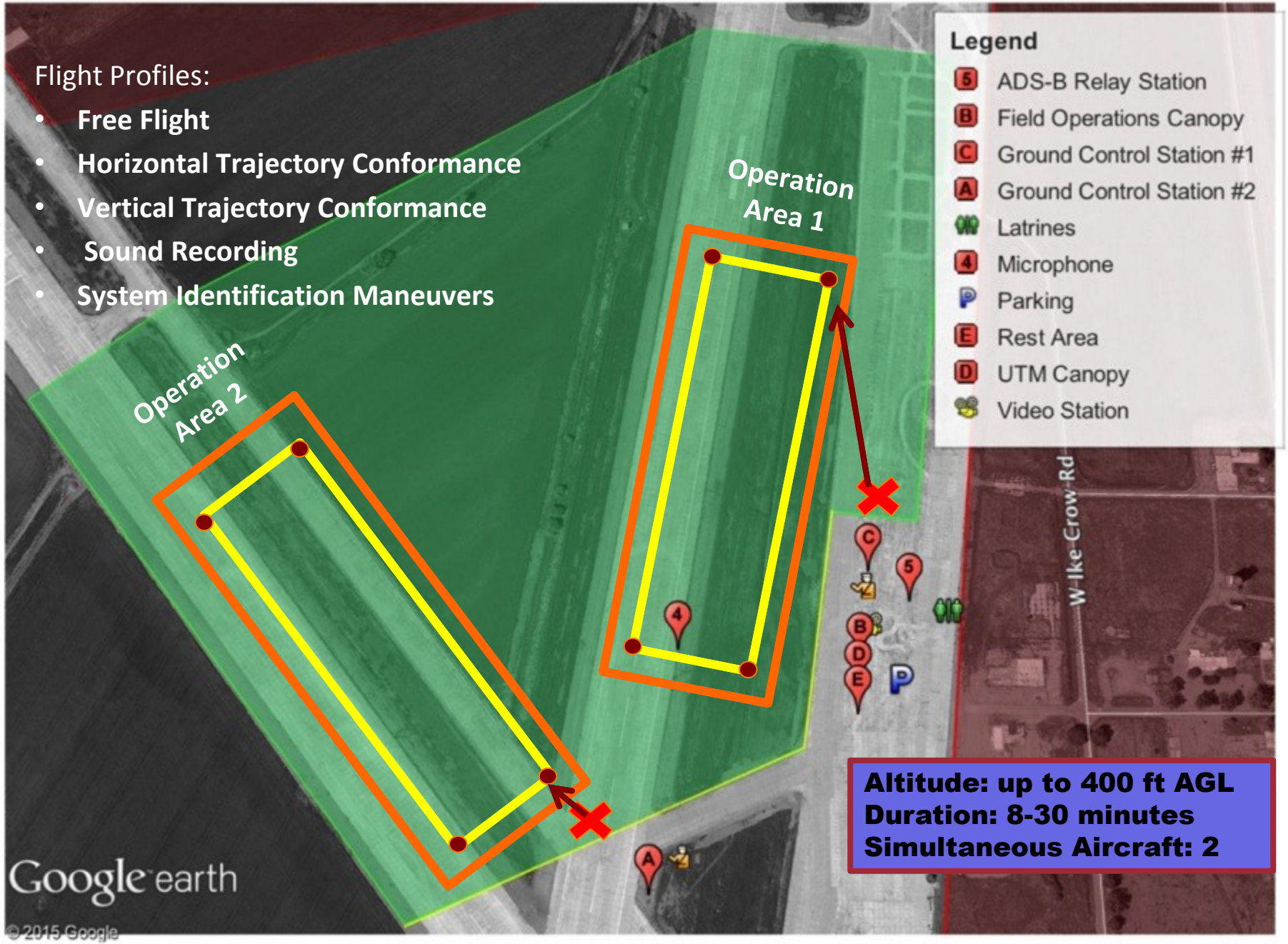
Objective 2: Collect Data on UAS Navigation Performance Error

Objective 1: Demonstrate UTM Prototype Features

Objective 3: Collect Data on Aircraft Tracking Performance



Objective 4: Collect Weather Observations for Forecasting Models


Flight Profiles:
• Free Flight
• Horizontal Trajectory Conformance
• Vertical Trajectory Conformance
• Sound Recording
• System Identification Maneuvers
Operation Area 1
Operation Area 2
Legend
ADS-B Relay Station
Field Operations Canopy
Ground Control Station #1
Ground Control Station #2
Latrines
Microphone
Parking
Rest Area
UTM Canopy
Video Station
W Ike Crow Rd
Altitude: up to 400 ft AGL
Duration: 8-30 minutes
Simultaneous Aircraft: 2
Google earth
© 2015 Google

TCL 1 Observations

Observations:

1

Ground equipment degraded performance and failed under high temperatures

High temperatures caused failures in ground control stations, routers, UTM computers, and Ethernet wiring.

2

Spectrum interference from unknown sources causes lost link conditions

Lost link conditions were invoked due to spectrum interference. Local farming equipment was hypothesized to have contributed to the incidents.

3

GPS degradation caused initiation of contingency management system

Inefficient satellites received during operations caused an aircraft to initiate a contingency management procedure and grounded another vehicle.

UAS and ground equipment should be rated for use based on the operational environment

Observations:

4 **Atmospheric conditions on the ground were not indicative of conditions aloft**

Despite flat terrain, wind and turbulence conditions varied on the ground as compared with 200—400 ft AGL.

5 **Line of sight was often difficult to maintain when flying multiple aircraft**

In the presence of other nearby operations, and raptors maintaining visual on aircraft was challenging for observers of the test.

6 **Tracking information for UAS was provided at rate that was insufficient**

The test used 5 second update rates for telemetry information which did not account for the dynamic changes in aircraft states, dropouts, quality of service connectivity, and human factors aspect of the displays. (Changed for TCL 2: 1 Hz or faster)

7 **Lack of airspace and operations information caused conflicting planned operations**

Flight crews had no airspace displays to allow them to de-conflict operations and this caused frequent operations that were in conflict.

All airspace users should have a common picture of the operating environment

TCL 2: Multiple BVLOS Operations

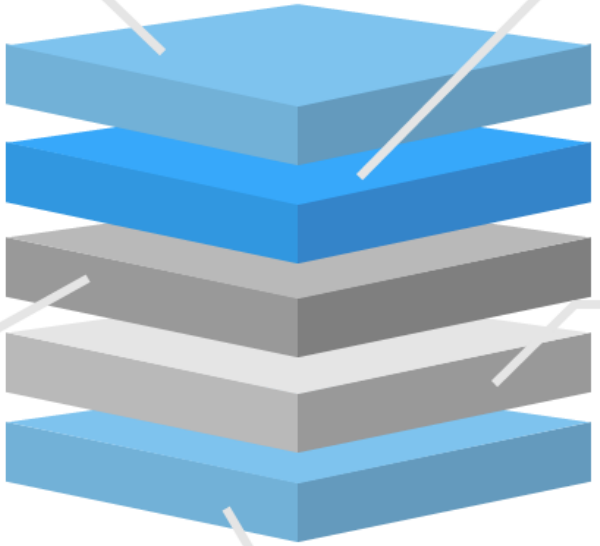
UTM TCL2: Scheduling and Executing Multiple BVLOS Operations

Conflict Alerts

Alert triggered by proximity to other aircraft

Intruder Alerts

Alert triggered from radar submitted warning regions to UTM research prototype



Contingency Alerts

Simulated in-flight emergency reported to the UTM research prototype and relayed to impacted operations

Flight Conformance Alerts

Alert triggered from departing from operational area and relayed to impacted operations

Priority Operations

Users with special privileges are given priority of the airspace and impacted operations are informed of any conflicts

Scheduling and tracking operations and contingency management

Test Range

UAS Range

Elevation: 5050 feet

Desert Terrain

Missions up to 500 ft

Operations at 5 Locations

SRHawk Radar

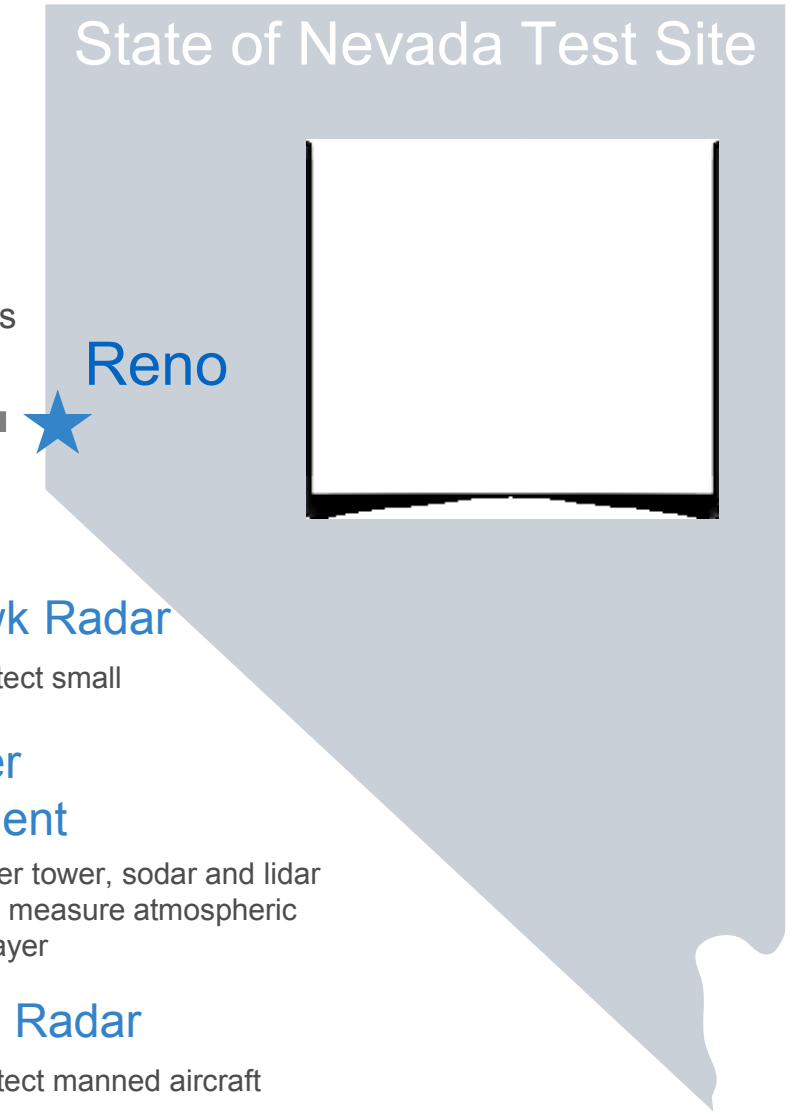
Used to detect small UAS

Weather Equipment

30 ft weather tower, sodar and lidar are used to measure atmospheric boundary layer

LSTAR Radar

Used to detect manned aircraft



UTM TCL 2 Demonstration Flight Operations

Live-Virtual Constructive Environment

Altitude Stratified Operations

Situation Awareness Displays

Critical alerts, operational plan information and map displays

2 + 3 = 5

Expanded

Flights up to 1.5 miles away from the pilot in command

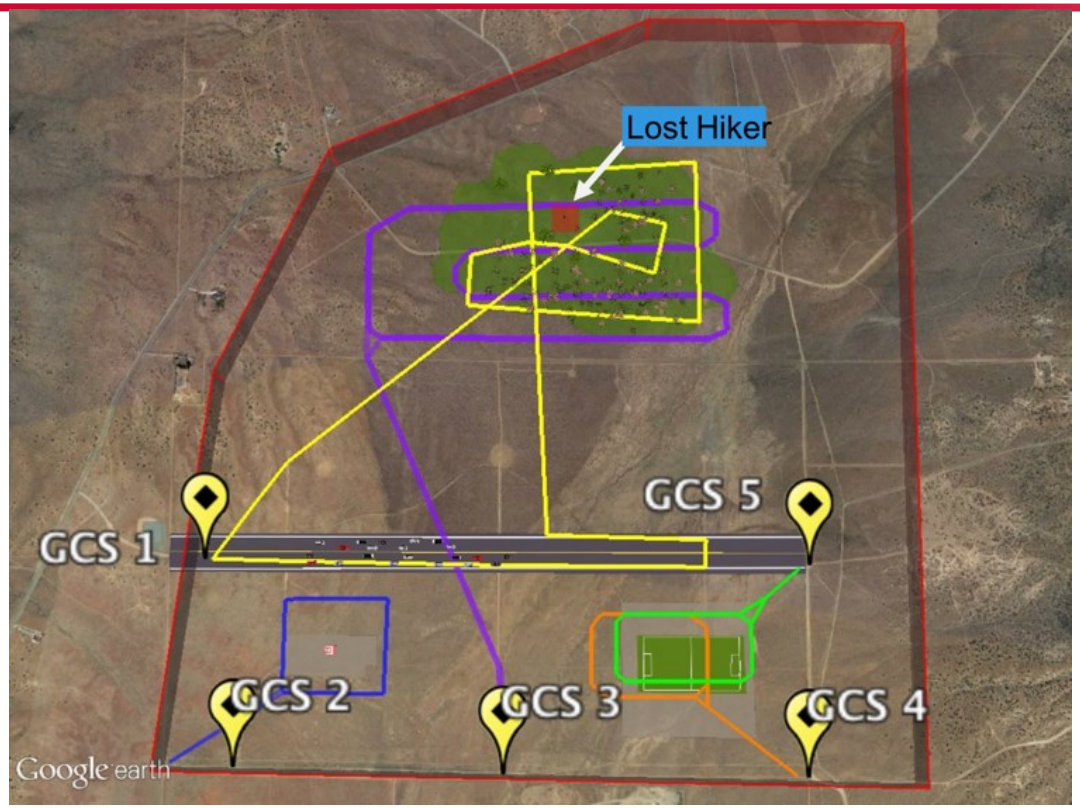
Visual Line of Sight

Hypothetical missions based on industry use cases

Simultaneous Operations

	SCENARIO 1 AGRICULTURE	SCENARIO 2 LOST HIKER	SCENARIO 3 OCEAN	SCENARIO 4 EARTHQUAKE
BVLOS	✓	✓	✓	✓
MULTIPLE BVLOS	✓		✓	
ALTITUDE STRATIFIED VLOS	✓	✓		✓
ALTITUDE STRATIFIED BVLOS			✓	
INTRUDER AIRCRAFT TRACKING	✓		✓	
INTRUDER AIRCRAFT CONFLICT ALERTS	✓		✓	
ROGUE AIRCRAFT CONFLICT ALERTS	✓			
DYNAMIC RE-ROUTING		✓		✓
CONTINGENCY MANAGEMENT CONFLICT ALERTS			✓	✓
PUBLIC SAFETY PRIORITY OPERATION		✓		
SIMULATED VIRTUAL AIRCRAFT		✓		✓

Scenario 2: Lost Hiker



Critical Events (in approximate order):

- **GCS1 (** submits all plans while logged in as special user
- **GCS3** sends message to RC "Reporting a lost hiker in area…" (*once all GCS have launched*)
- **ALL GCS** receive message from RC "Simulated lost hiker in area…" (*once all GCS have launched*)
- **GCS1** submits 2nd plan with special permissions *logged in as special user (*after 2 minute hover & lost hiker message*)
- **GCS3** receives UTM system message "first responder in proximity..." and ABORTS (*after GCS1's 2 min hover & lost hiker message*)
- **GCS5** submits 2nd plan – REJECTED for special permissions operation – does not launch (*after landing plan 1, while GCS1 is still flying*)

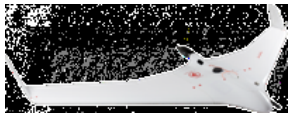
UTM TCL 2 Demonstration Highlights

Days of Flight
5

14 Partner Organizations

2 Simultaneous Altitude Stratified Expanded Operations

11 UAS Platforms



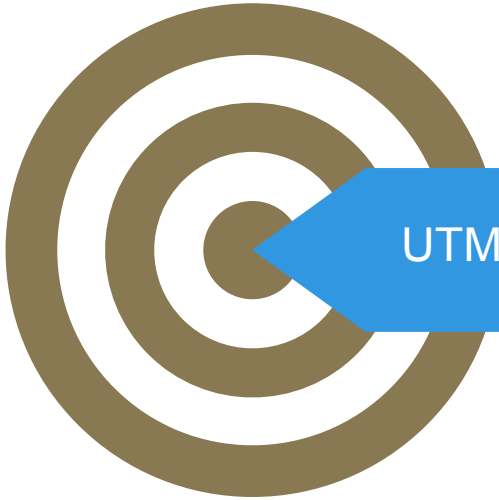
30
Minutes per scenario

4
Scenarios

74
Flights

13.5
Flight Hours

UTM Research Platform

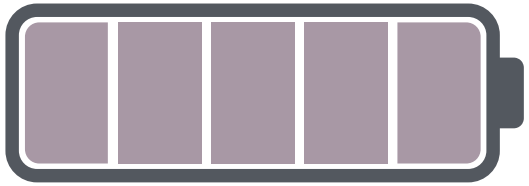


UTM concept and research platform supported BVLOS

UTM Core Principles and Guiding Tenet	Tested Feature
UAS should avoid each other	Scheduling and Planning Conformance Alerting Proximity Alerting Separation by Segregation (e.g. Geo-fencing)
UAS should avoid manned aircraft	Intruder Alerting Separation by Notification (e.g. NOTAM)
UAS operators should have complete awareness of all constraints in the airspace	UTM Mobile Application Contingency Management Alerts
Public safety UAS have priority within the airspace	Priority Operations
Flexibility where possible and structure where necessary	Altitude Stratification Dynamic Re-routing 4D Segmented Flight Plans

TCL 2 Findings

Impact of Weather



Nominal Aircraft Endurance

Multi-Rotors: 20-40 minutes

Fixed-Wing: 45-200+ minutes

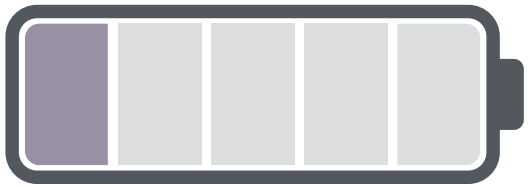
Reno-Stead Elevation: 5,050 ft

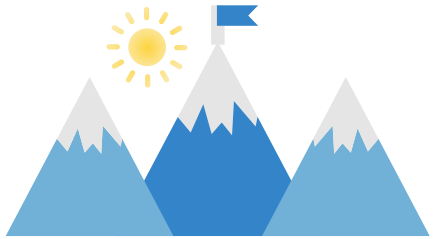
Cool Temperatures

Density Altitude: 4,000 ft

Winds: 5-35 knots

Aircraft encountered **thermals**, **microbursts** and **high winds** which resulted in **reduced endurance** and degraded flight plan conformance





Warm Temperatures

Density Altitude: 9,000+ ft

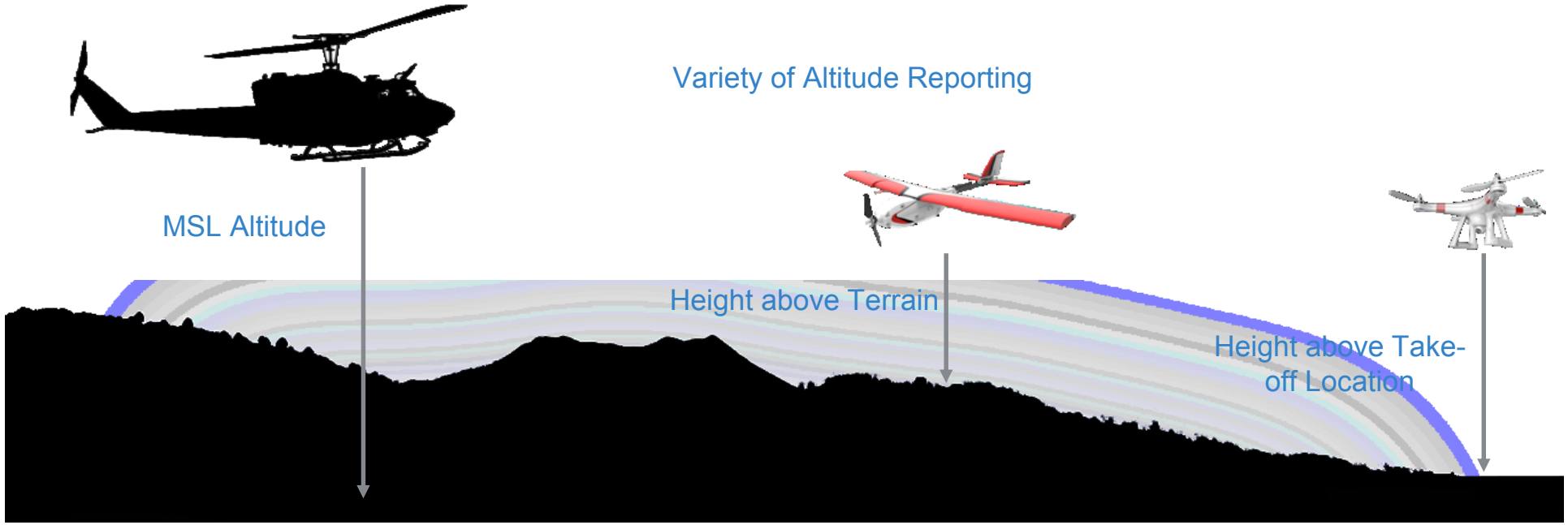
Winds: 5-15 knots

Aircraft experienced substantially **shorter endurance**

UAS should be tested and rated against different operational environments

Inconsistent Altitude Reporting

Increased risk of controlled flight into terrain and airborne collision hazard



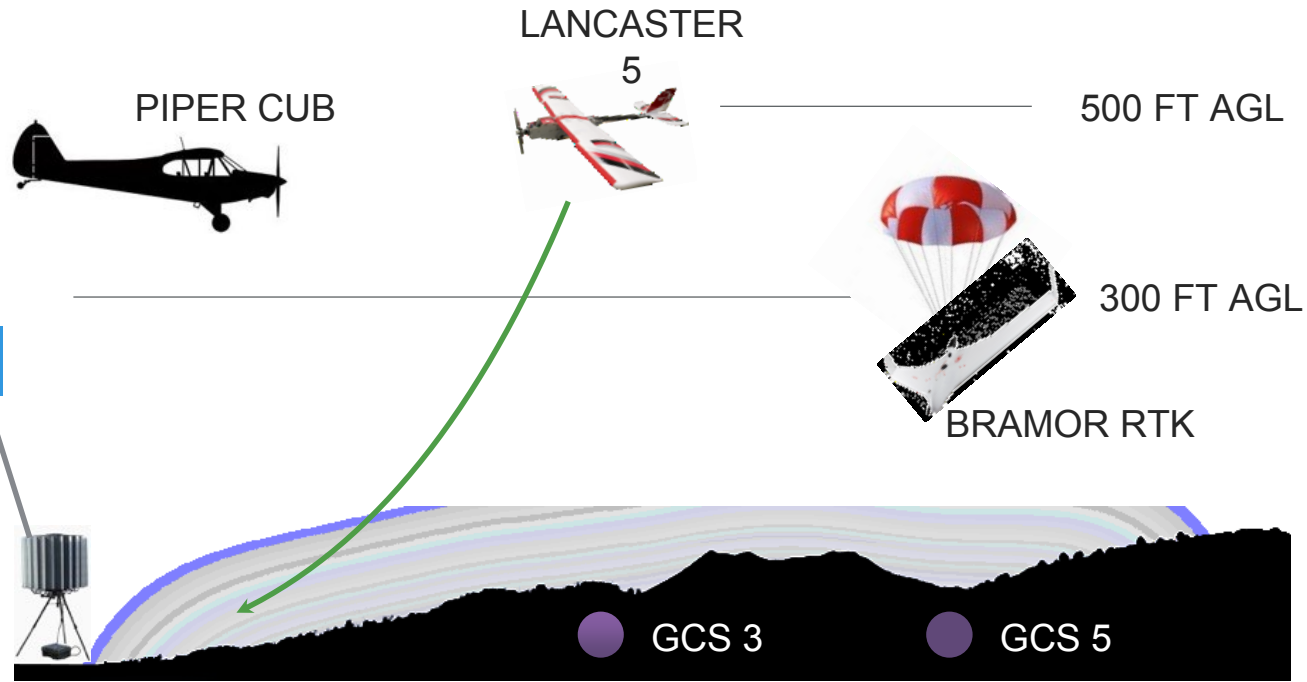
Altitude Reporting should be consistent or translatable across airspace users

Key Findings using UTM to support Expanded Operations

Manned Aircraft Test Range Incursion on 10/22/2016

Surveillance enhanced situation awareness

Surveillance may not be a requirement in all TCL 2 environments, however for areas with increased manned air traffic, surveillance provided increased situation awareness and should be required.



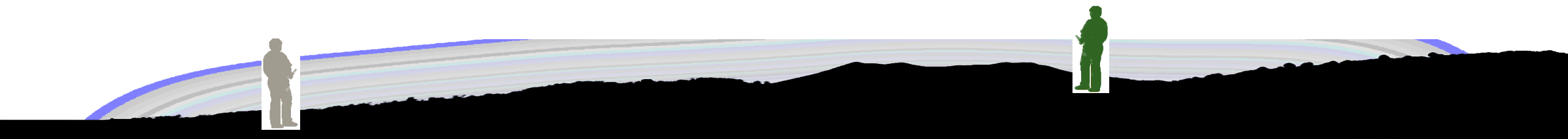
Preliminary Recommendations for Initial Multiple BVLOS Operations (based on TCL-2 evaluations)

01 Operators need to **display airspace information** and have access to other operator's operational intent and contingency actions in off-nominal conditions (common UTM picture was useful)

02 In the absence of acceptable weather products, **atmospheric conditions** should be **self-reported** from **GCS** and **UAS**

03 Initial BVLOS should **avoid altitude stratification**, until altitude standard, V2V

04 **Altitude reporting** should be **standardized** and consistent/translatable to current airspace users



Next Steps

TCL 2 National Safe UAS Integration Campaign

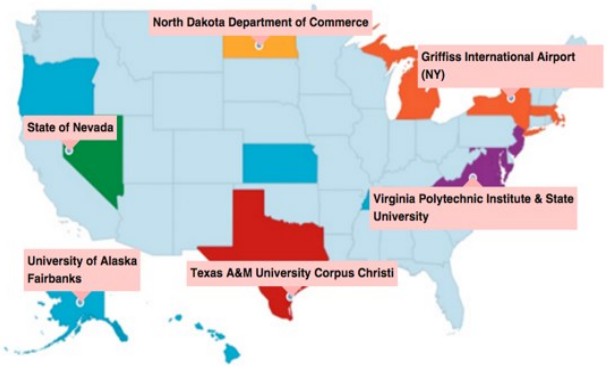
What: Demonstrate and evaluate critical elements of diverse multiple BVLOS operations, 4 different vehicles from each site flown under UTM

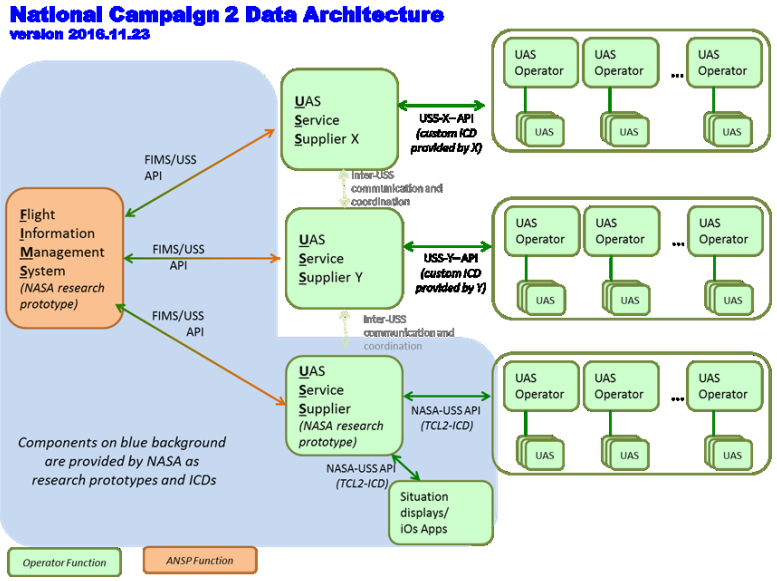
Demonstrate architecture with multiple Operators, UAS Service Suppliers and Flight Information Management System (FIMS)

Where: 6 FAA UAS Test Sites

Who: NASA, Test Sites, ~40 partners

When: 15 May – 9 June 2017





Test Site	USS Tech	Geofence Tech	Ground-based SAA	Airborne SAA	CNS	Human Factors
Alaska		X			X	
Nevada	X	X	X	X	X	X
New York	X	X			X	
North Dakota	X	X	X		X	X
Texas				X		
Virginia	X			X		

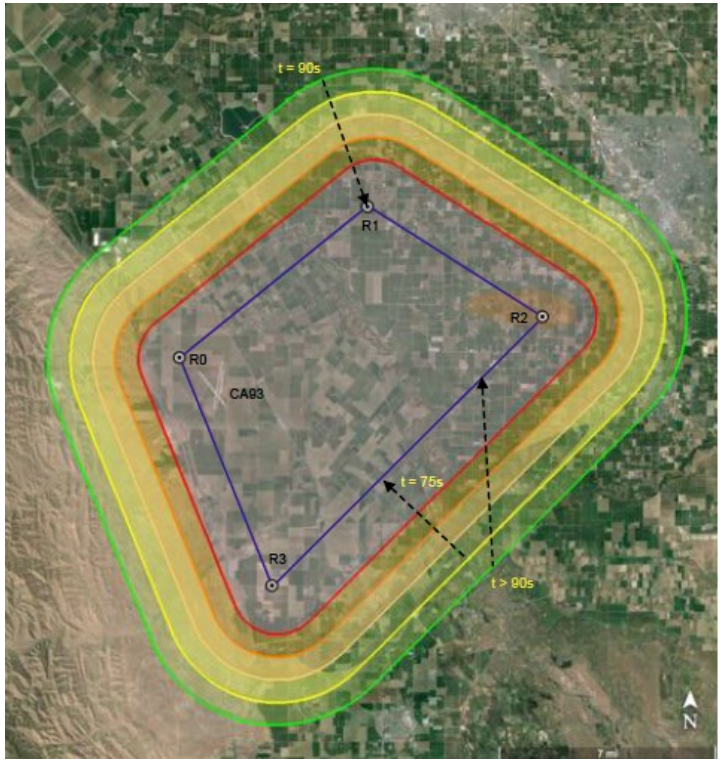
The UTM concept and research platform is exercised by all industry and FAA test sites

TCL 3 Evaluations (preparations underway)

High level objectives of TCL 3 evaluations

- System Level Evaluation
  - Contingency Management /Off-Nominal Conditions
  - Priority Operations and Airspace and Ground Constraints
- Separation
  - Non-cooperative aircraft
  - Cooperative Aircraft
  - Ground Obstacles
- Communication and Navigation
  - Direct Communication and Control (e.g. radio controlled)
  - Distributed Communication (e.g. cellular network, mesh networks)
- Navigation (close to people and buildings, terrestrial and satellite-based)
  - Data gathering for modeling, measurement and forecasting of weather
  - UAS/USS weather integration

TCL 3 Evaluations will include testing at Crows Landing, CA in Fall 2017 using COA 2016-WSA-46 that authorizes NASA to conduct BVLOS operations with small UAS at Crows Landing, CA using a radar for separation (instead of visual observers)



Summary

- Very active collaboration with FAA and industry
- UTM construct is adopted globally (e.g., J-UTM, K-UTM, SESAR, etc.)
- FAA-NASA UTM RTT construct has been very productive
- Next big impact will be UTM pilot and path towards initial operations

QUESTIONS?

Embracing innovation in aviation while respecting its safety tradition